Smooth Pursuit of Flicker-defined Motion

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NASA Ames Research Center

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Start timer

My collaborator

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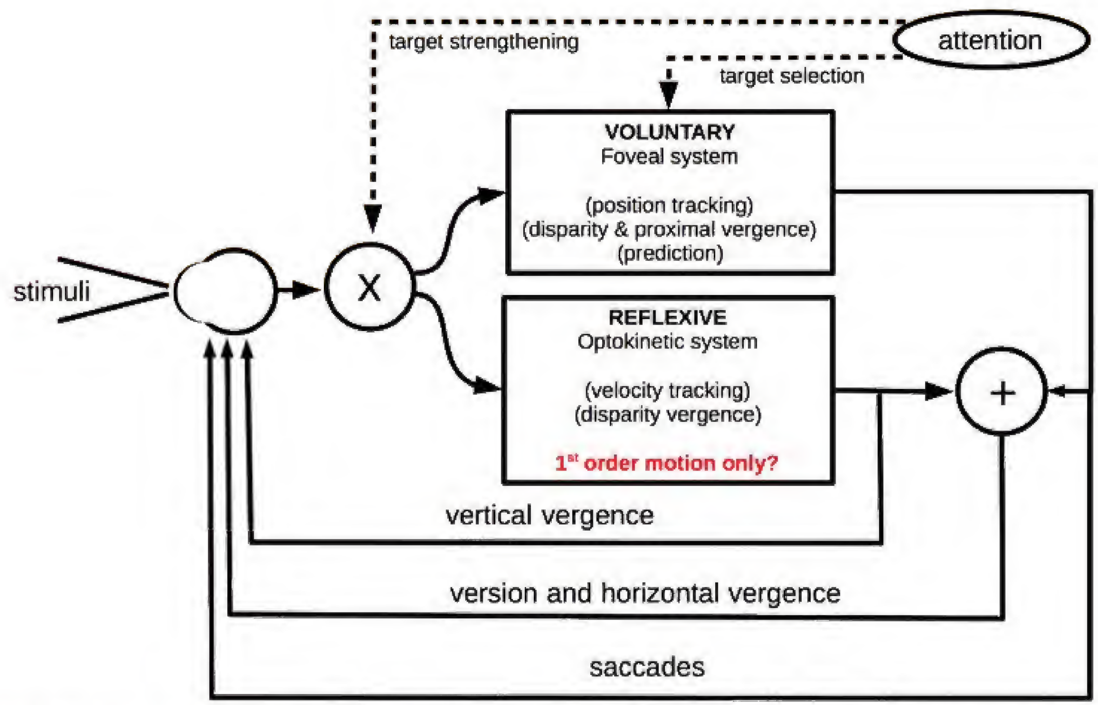
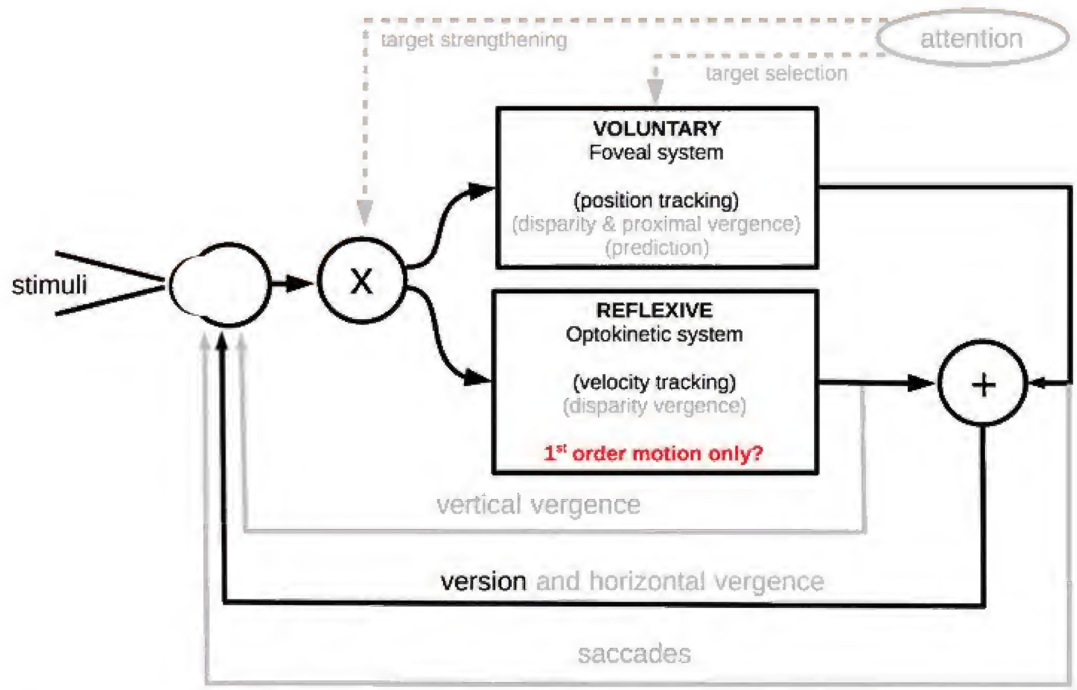
Univ. Houston College of Optometry

A (familiar?) Model of Eye Movement Control



Mulligan, J. B., Stevenson, S. B., and Cormack, L. K. (2013). "Reflexive and voluntary control of smooth eye movements." In B. E. Rogowitz, T. N. Pappas, and H. de Ridder (eds.), Human Vision and Electronic Imaging XVIII, Proc. SPIE vol. 8651.

The topic of today's talk



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The delayed feedback paradigm

JOURNAL OF NEUROPHYSIOLOGY
Vol. 67, No. 3, March 1992. *Printed in U.S.A.*

Effect of Changing Feedback Delay on Spontaneous Oscillations in Smooth Pursuit Eye Movements of Monkeys

D. GOLDREICH, R. J. KRAUZLIS, AND S. G. LISBERGER
Department of Physiology, W. M. Keck Foundation Center for Integrative Neuroscience, and Neuroscience Graduate Program, University of California, San Francisco, California 94143

Boxology 201

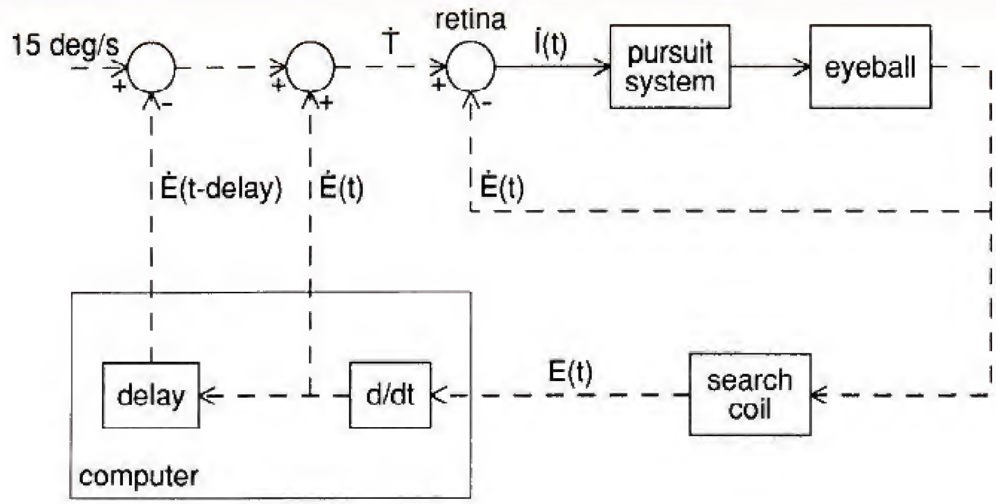
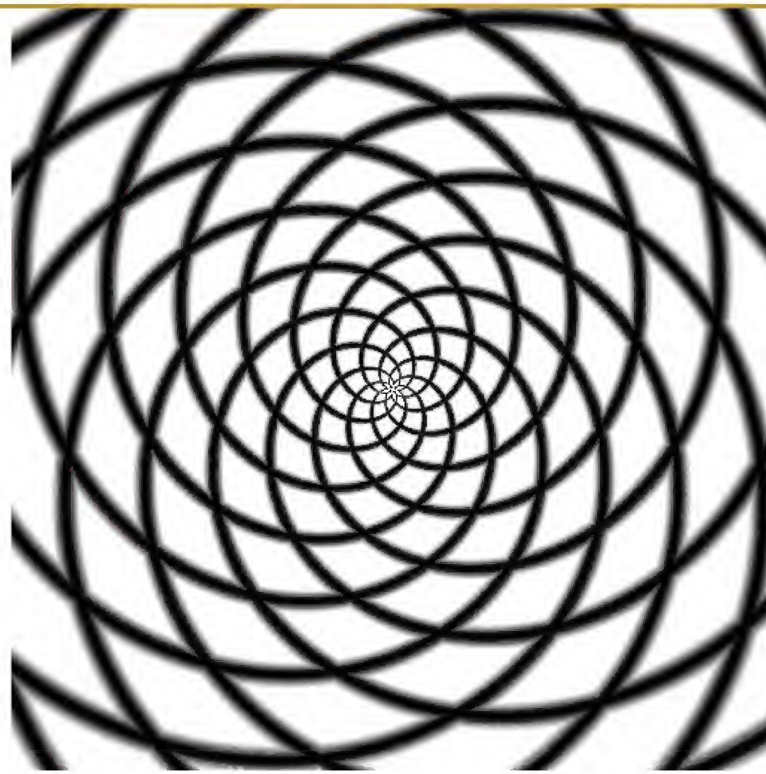


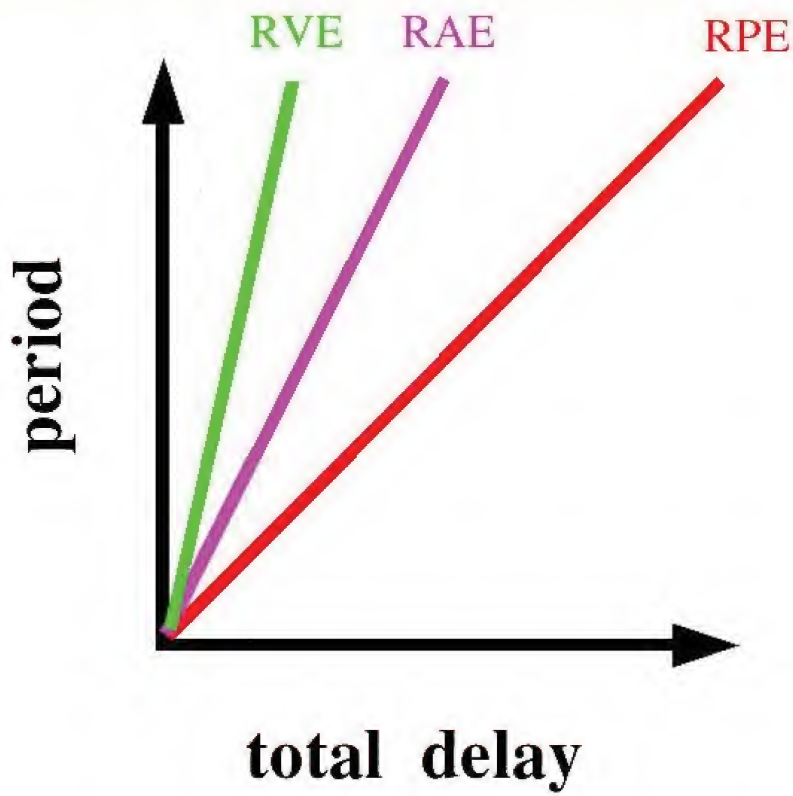
Figure from Goldreich, Krauzlis & Lisberger (1992)

Try it yourself!

- Launch demo



Period vs. delay- summary



Show math

A little math - definitions

$e(t)$	eye position (EP)
$p(t)$	target position
$\dot{e}(t)$	eye velocity (EV)
$\dot{p}(t)$	target velocity
$\ddot{e}(t)$	eye acceleration (EA)
$\ddot{p}(t)$	target acceleration

A little math - definitions

$p(t) - e(t)$	retinal position error (RPE)
$\dot{p}(t) - \dot{e}(t)$	retinal velocity error (RVE)
$\ddot{p}(t) - \ddot{e}(t)$	retinal acceleration error (RAE)

A little math - control laws

$$\ddot{e}(t) = k_1\left[p(t-\delta_1) - e(t-\delta_1)\right]$$ RPE drives EA

$$\ddot{e}(t) = k_2\left[\dot{p}(t-\delta_1) - \dot{e}(t-\delta_1)\right]$$ RVE drives EA

$$\ddot{e}(t) = k_3\left[\ddot{p}(t-\delta_1) - \ddot{e}(t-\delta_1)\right]$$ RAE drives EA

A little math - control laws

$$\dot{e}(t) = k_2\left[\,p(t-\delta_1) - e(t-\delta_1)\,\right]$$

RPE drives EV

$$\ddot{e}(t) = k_2\left[\,\dot{p}(t-\delta_1) - \dot{e}(t-\delta_1)\,\right]$$

RVE drives EA

A little math - possible stimuli

$p(t) = k$	stationary target
$p(t) = e(t)$	ideal stabilization
$p(t) = e(t - \varepsilon)$	lab stabilization
$p(t) = e(t) + d(t)$	open-loop
$p(t) = e(t) - e(t - \delta_2)$	transient stabilization

A little math - delayed feedback & model

$$\mathrm{p}(t) = \mathrm{e}(t) - \mathrm{e}(t-\delta_2)$$ transient stabilization

$$\ddot{\mathrm{e}}(t) = k_1\left[\mathrm{p}(t-\delta_1) - \mathrm{e}(t-\delta_1)\right]$$ RPE drives EA

$$\ddot{\mathrm{e}}(t) = k_1\left[\mathrm{e}(t-\delta_1) - \mathrm{e}(t-\delta_1-\delta_2) - \mathrm{e}(t-\delta_1)\right]$$

$$\ddot{\mathrm{e}}(t) = -k_1 \mathrm{e}(t-\delta_1-\delta_2)$$

$$\ddot{\mathrm{e}}(t) = -k_1\, \mathrm{e}(t-\delta)$$

A little math - sinusoidal solution

$$\ddot{e}(t) = -k_1 \, e(t - \delta)$$

$e(t) = e^{i\omega t}$ trial solution

satisfied if $k_1 = \omega^2$ and $\lambda = \delta$,

where $\lambda \equiv \dfrac{2\pi}{\omega}$.

Period vs. delay- summary

$\lambda = \delta$ RPE drives EA

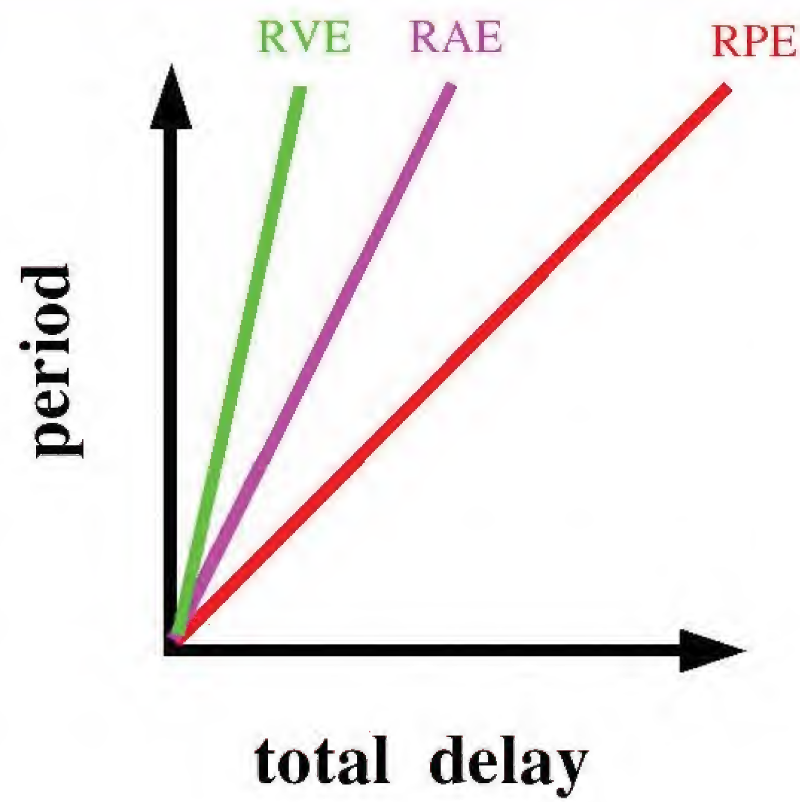
$\lambda = 4\delta$ RVE drives EA

$\lambda = 2\delta$ RAE drives EA

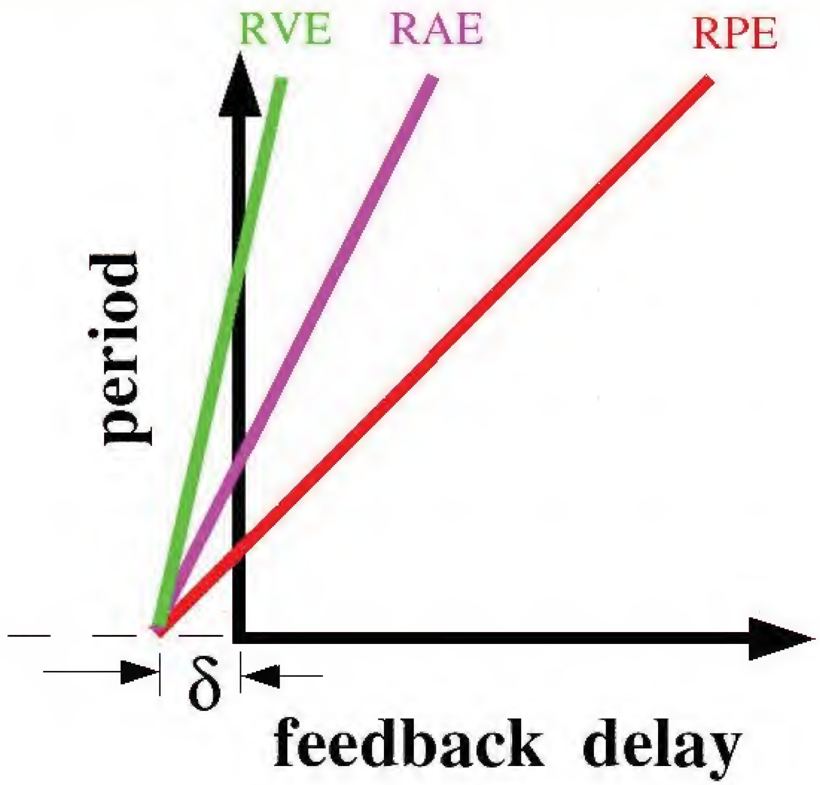
$$\lambda = \frac{4\delta}{4n + 2 - N_d}$$

$\lambda = \frac{4}{3}\delta$ RPE drives eye jerk

Period vs. delay- summary



Period vs. delay- summary



Period vs. delay - summary

SPONTANEOUS OSCILLATIONS IN PURSUIT 629

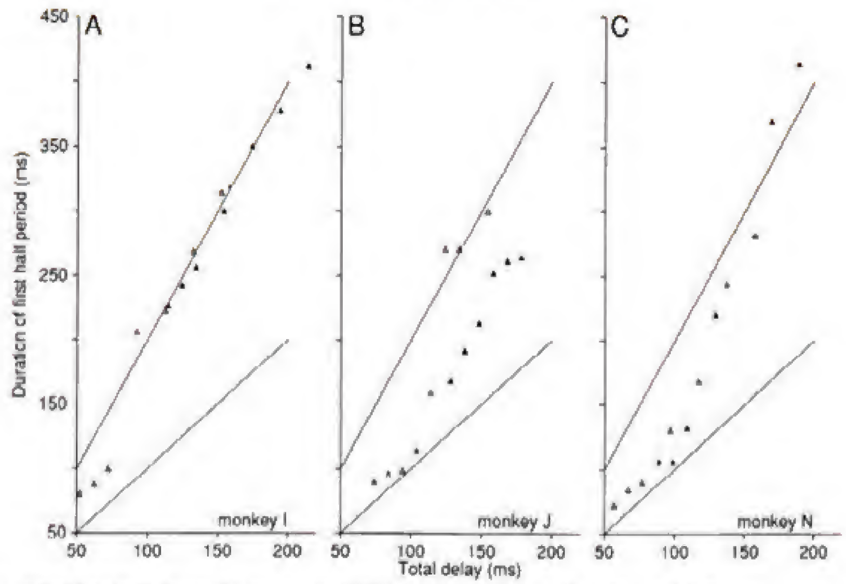
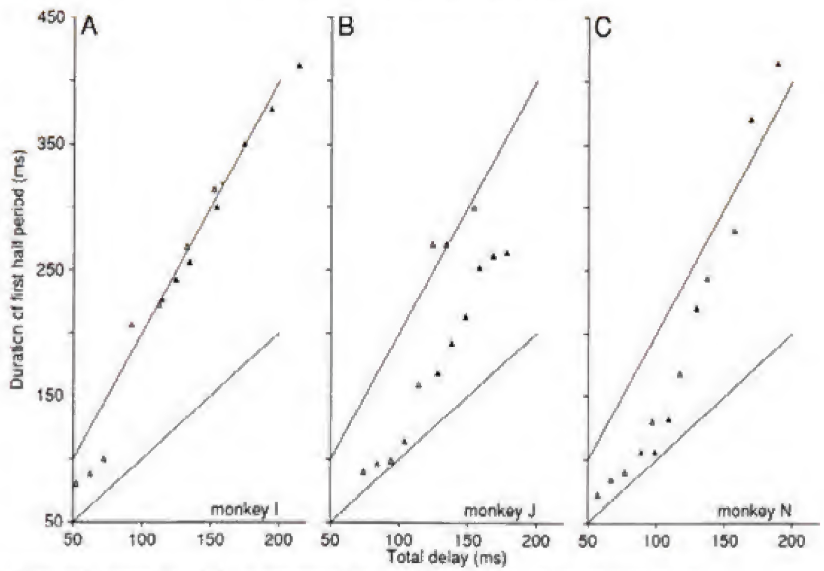


FIG. 4. Relationship between the period of spontaneous oscillation and the total feedback delay. Each graph plots the duration of the 1st half period of the oscillations as a function of the sum of the natural latency for pursuit and the artificial delay added by the computer. *A–C*: results for 3 monkeys. Open symbols represent data obtained with a big, bright target and short natural delays, and filled symbols represent data obtained with a small, dim target and longer natural delays. The lines describe the relationships: period of oscillation equals 2 or 4 times total delay. As described in the APPENDIX, these lines represent the theoretical limits of the relationship between the period of oscillation and the total delay. The speeds of target motion were 30°/s in *monkeys I* and *N* and 15°/s in *monkey J*.

Figure from Goldreich, Krauzlis & Lisberger (1992)

Period vs. delay - summary

SPONTANEOUS OSCILLATIONS IN PURSUIT 629



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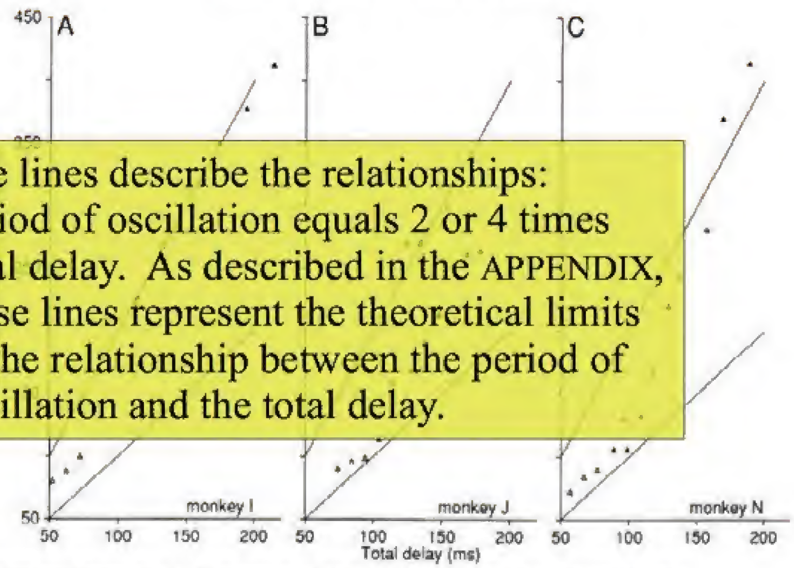
Period vs. delay - summary



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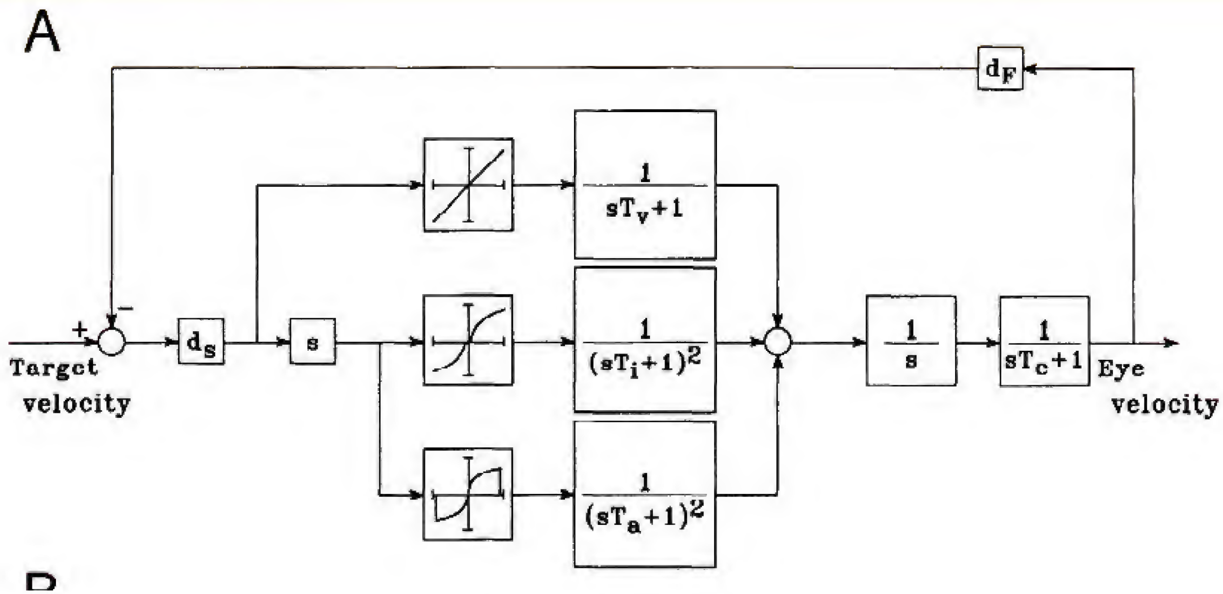
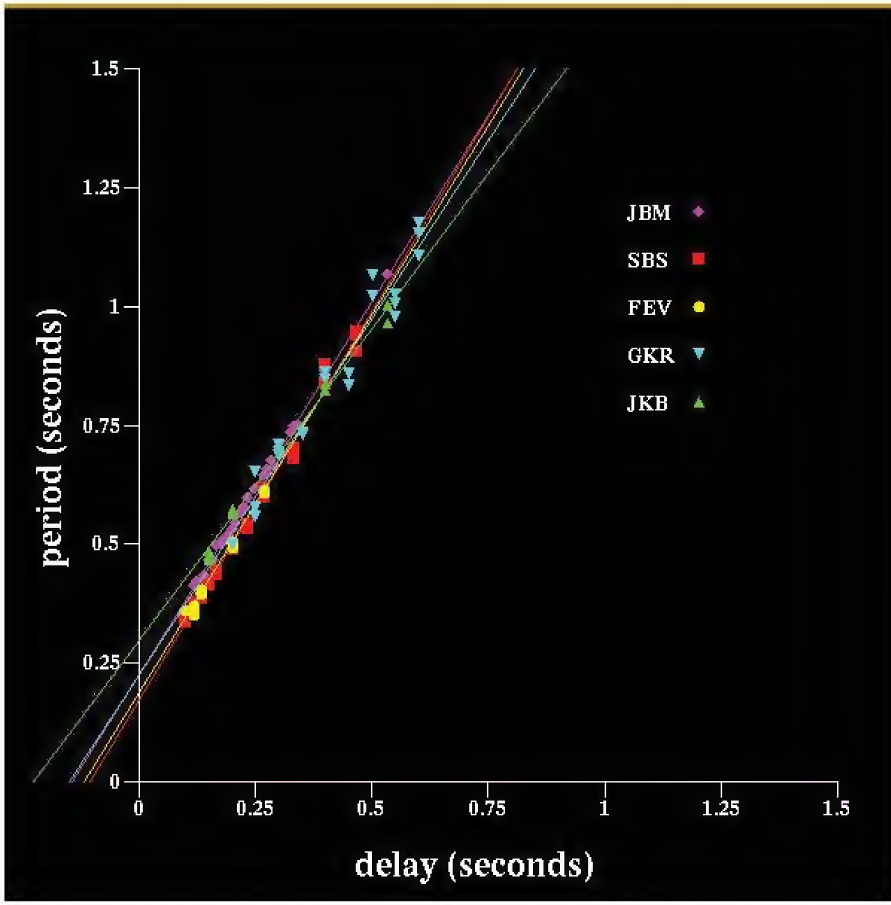


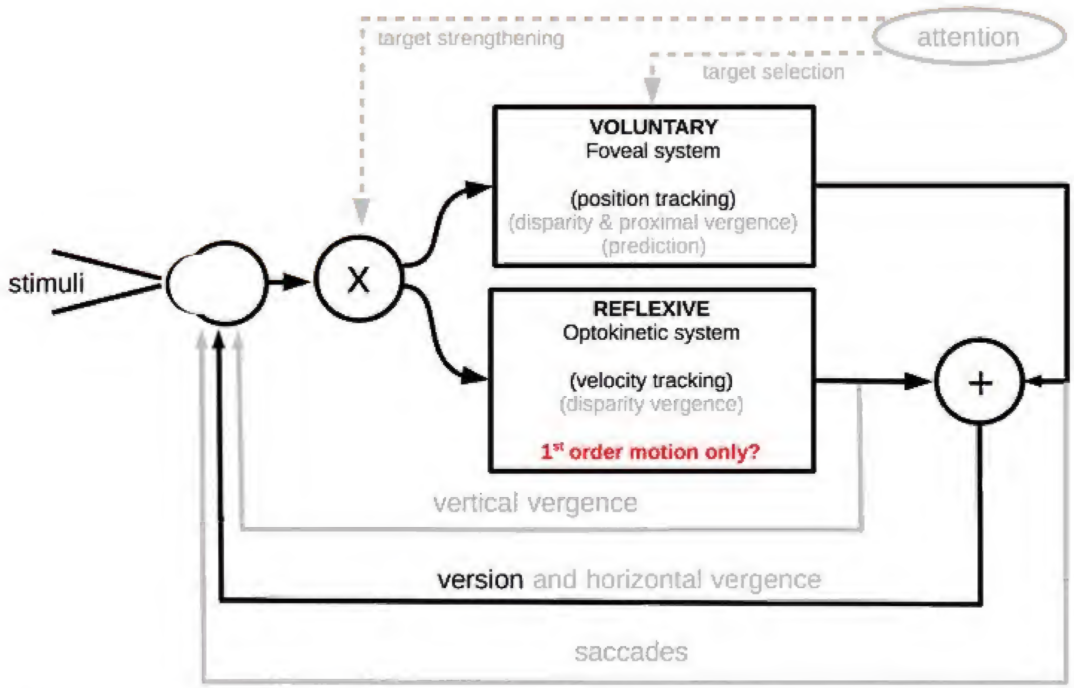
Figure from Goldreich, Krauzlis & Lisberger (1992)

Old results - laser spot on spiral background



Slopes: 1.3 - 1.6

The topic of today's talk



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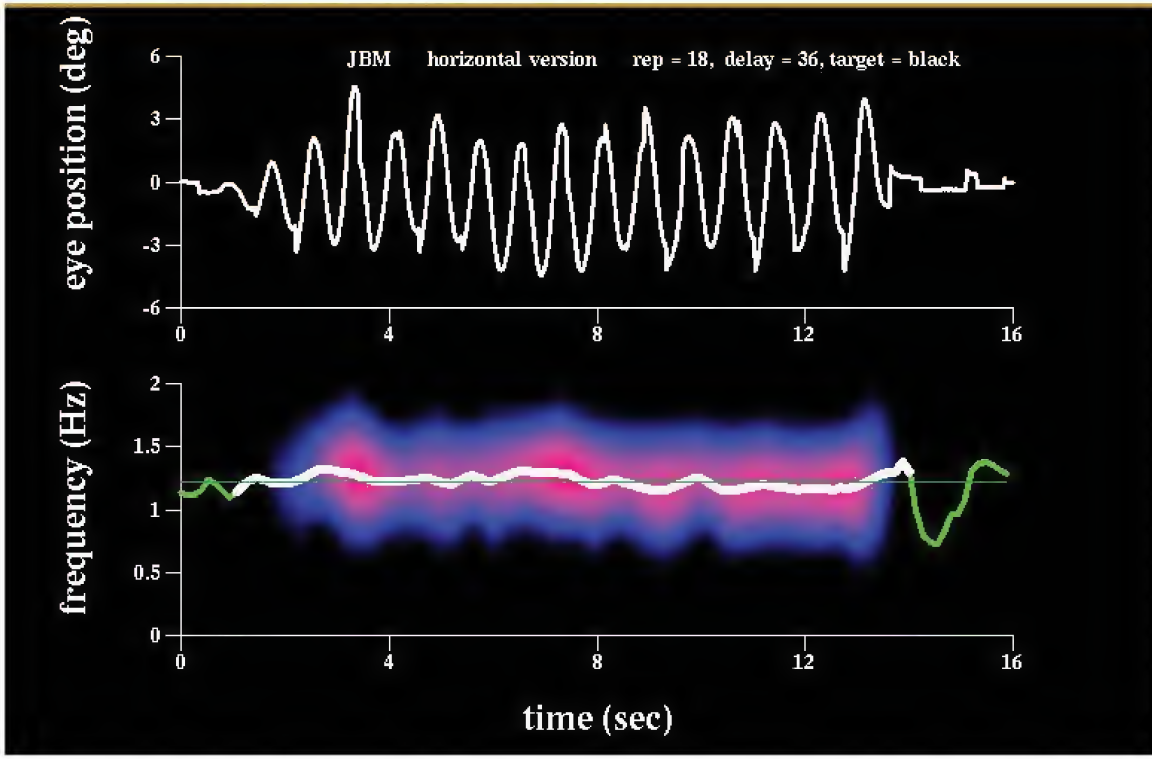
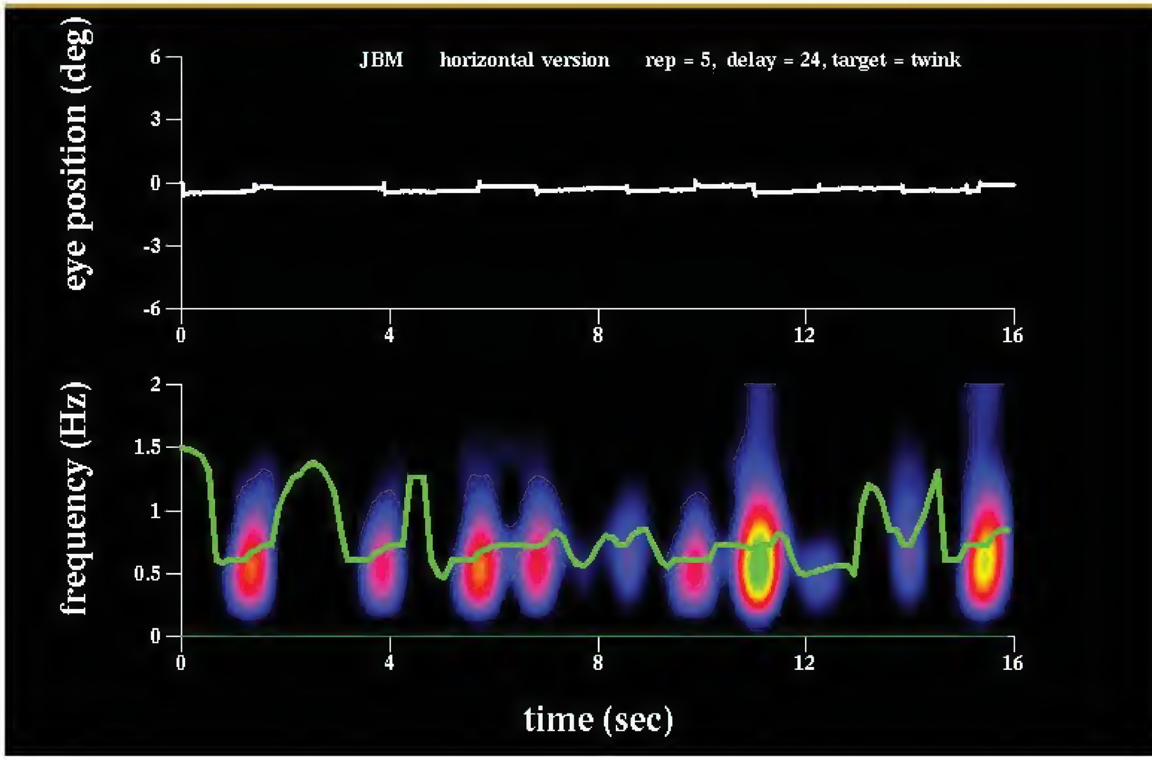
The stimulus - flicker defined motion

- Black/white pattern minimizes effects of gamma nonlinearity
- Carrier pattern: dense (Julesz) random dot pattern
- Stimulus pattern: probability of dot polarity reversal
- Real-time generation via nVidia CUDA (120 Hz to CRT)
- Demos

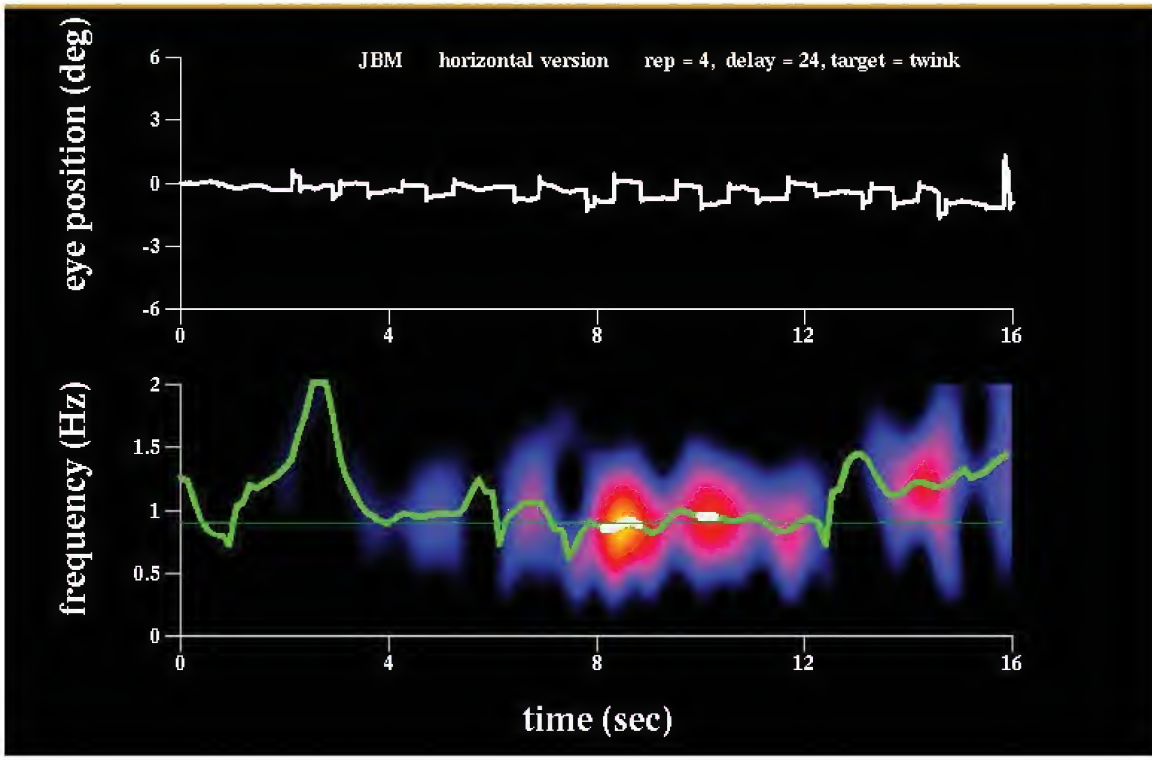
Sample trial - black spot



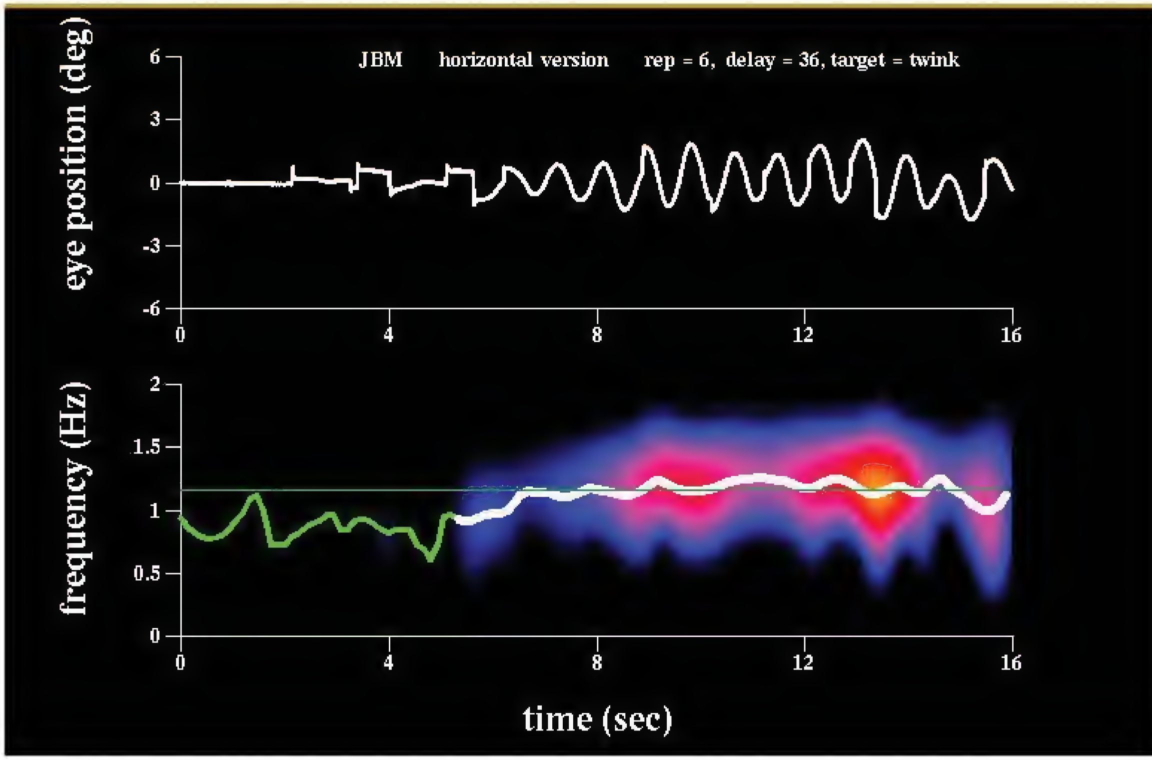
First trial - twinkle spot



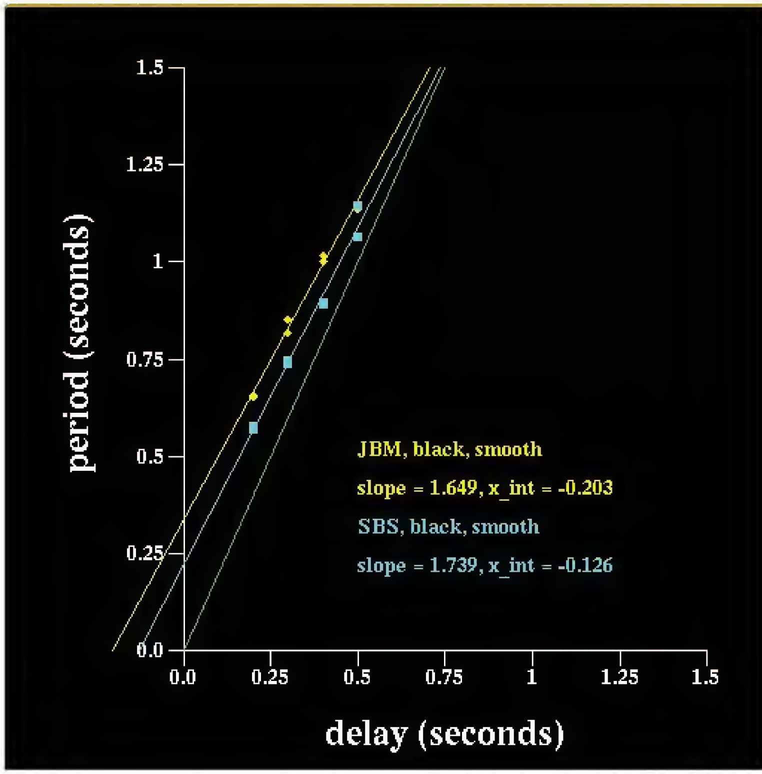
Later trial - twinkle spot



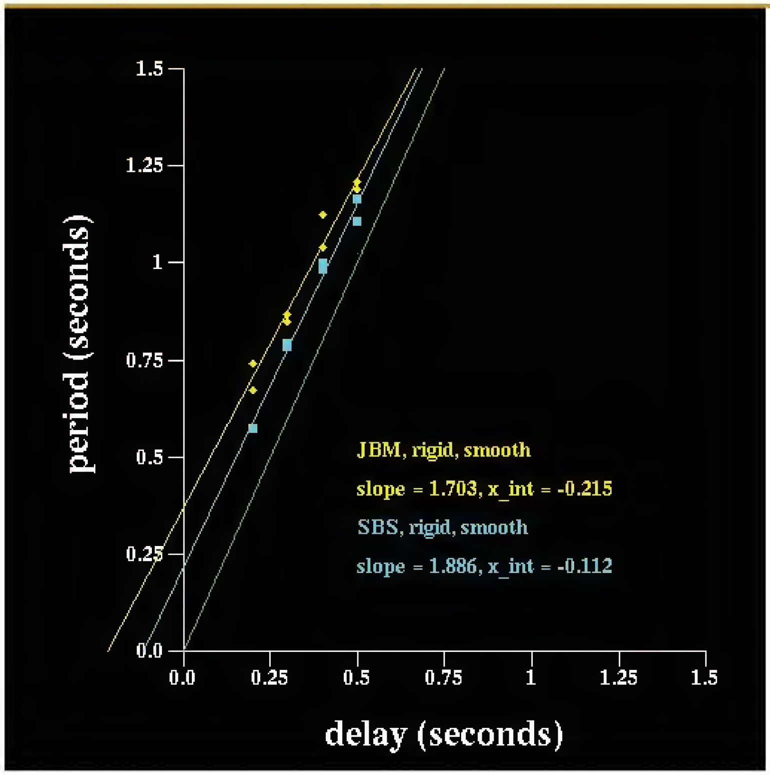
Later trial - twinkle spot



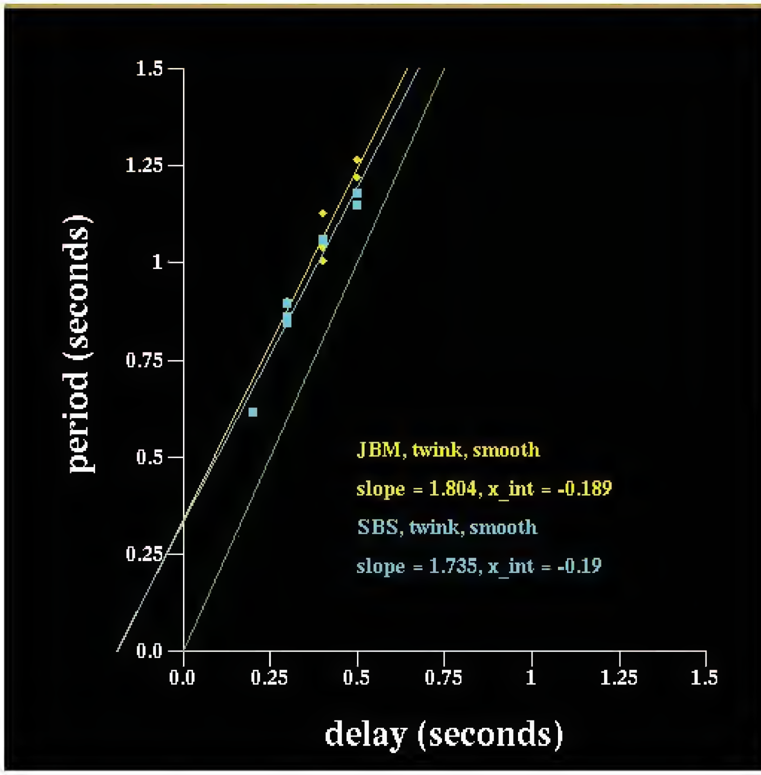
Period-vs-Delay - black spot



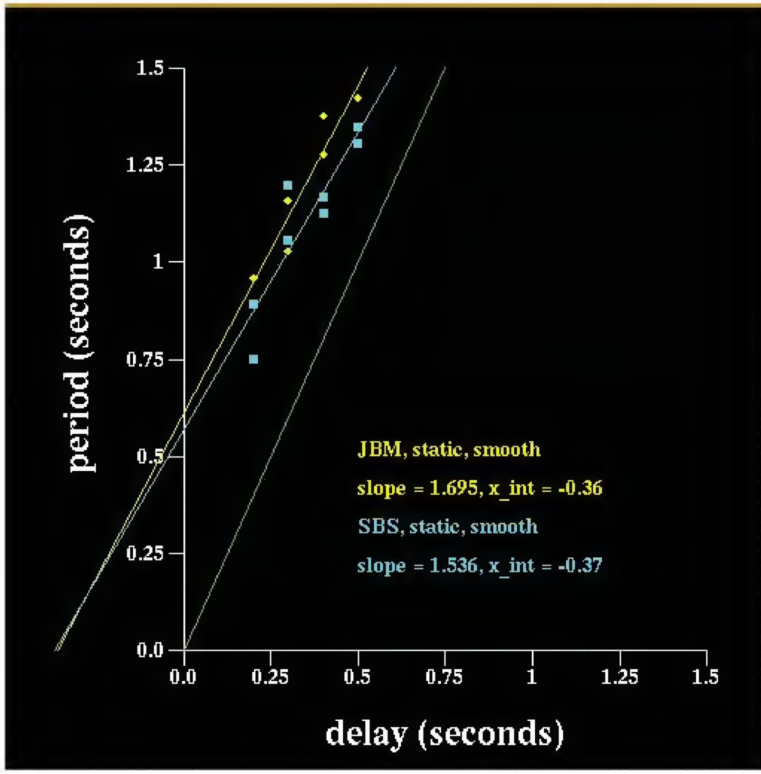
Period-vs-Delay - rigid spot



Period-vs-Delay - twinkle spot



Period-vs-Delay - static spot



Summary

- Flicker-defined motion produces weak motion sensation
- But response to flicker-defined spot is similar to that of standard target
- Largest difference seen for cue-conflict "static" spot
- BUT only small change in period-versus-delay slope!?
- Modeling required to understand the role of position inputs to pursuit

- THANK YOU!